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Report No. IIIRI-B6143

Final Report

THE DEVELOPMENT OF A COMPOSITE CONSUMABLE INSERT FOR SUBMERGED ARC WELDING

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Report Documentation Page

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Report No. IITRI-B6143

Final Report

THE DEVELOPMENT OF A COMPOSITE CONSUMABLE INSERT FOR SUBMERGED ARC WELDING

Prepared for:

Bethlehem Steel Corporation
Sparrows Point, Maryland 21219

Attention: Mr. W. C. Brayton
Assistant General Manager

Prepared by:

IIT Research Institute
10 W. 35th Street
Chicago, Illinois 60616
Mr. E. R. Bangs

August 1980

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Research Institute

EXECUTIVE SUMMARY

The composite development program was initiated by Mr. William S. Brayton, at the time Chairman of the Shipbuilding Committee of the Maritime Administration. The problem was related to the welding of heavy thickness plate that requires welding from both sides. When the submerged arc process was utilized to weld the butt joint in large flat plate structures, the repositioning of the plate for welding of the reverse side was a costly time consuming procedure. The objective was to develop a joint design and modified submerged arc welding process that would enable full penetration welding from one side. The modified process would eliminate the need for repositioning of the plate.

The concept devised by the writer was to develop a flux filled composite wire structure that could be used as a preplaced insert or backing strip to support the molten puddle during welding and enable formation of a sound root area reinforcement. As a backing strip the composite could be easily removed after welding by light grinding.

Initial analytical work was performed at the IITRI welding laboratory. Composite structures were sintered in 0.008" diameter wire mesh at densities of 15, 35, 40, 47 and 57 percent. Due to availability,.a stainless steel type 304 wire was used for the structures. The sintered structures were filled with a Lincoln A-XXX1O Flux. Two joint designs were evaluated, they included a single groove butt using the composite as a consumable insert and a single groove butt using the composite as a backing strip. Submerged arc welded samples in both designs demonstrated that both the insert and backing strip concepts had the potential to work. In weld joints where composite wire density and powder fill density was uniform, welds of good commercial quality were attainable. Problems of burnthrough were encountered where wire mesh density was low. Chain porosity was also encountered and was attributed to moisture contamination in the flux filling.

Composite backing strips were easily removed with a grinding wheel. Uncovered root area reinforcements were free from heavy oxide scale and other surface defects. Sample *structures were* manufactured for shipyard evaluation and forwarded to the Sparrows Point Yard. Welding studies at the shipyard were never completed.

At the time of Mr. Brayton's retirement further composite work was being considered. In addition to directing new effort to resolving the. burnthrough and density problems its competitive position with ceramic tiles was to be evaluated.

IIT Research Institute
10 West 35 Street, Chicago, Illinois 60616
312/567-4000

13 June 1977
IITRI-B6143-1,2

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.JUN 14 1977

C. P.

Bethlehem Steel Corporation
Sparrows Point, Maryland 21219

Attention: Mr. W. C. Brayton
Assistant General Manager

Subject: Report No. IITRI-B6143-1, 2, "Development of a Ccmposite Consumable Insert for Submerged Arc Welding," April-May 1977 Summary Report

Dear Bill:

After an unfortunate delay due to contractual problems, activities started in the program in late April.

As shown on the attached schedule we are initiating a limited amount of welding trials immediately in random available felt structures in order to make up for time lost earlier. The experimental fiber structures will in no way represent the chemical composition of the filled structures used in the program but will give us some indication of the solidification characteristics of the filled insert at a given density and wire or fiber size.

The flux (Lincoln A-xxx10) is already available in our welding lab, and is ready for use along with the Lincoln L-61 filler wire (5/64 in. diameter). A "hand piece" manual submerged arc welding gun (Lincoln Model K-113, 600 amperes) will be used with a TEK TRAN 800 ampere linear slope solid state power supply. Figure la includes a sketch of the anticipated weld joint design prior to welding and b shows the weld joint results we will be striving for upon completion of one weld pass.

In a parallel effort we are presently producing a series of sintered filter structures that when flux filled will conform to the following requirements:

material - 1008 or 1010 composition

wire size - .008-.010 in. wire diameter

density - 30, 40, and 50 percent

Cross sectional dimension - 1/2 x 1 in.

flux - fill balance of three sintered fiber structure densities.

Mr. W.C. Brayton
Page 2
13 June 1977

Problems are anticipated in developing a technique for flux filling. Testing will be required to identify the proper relationship of structure density and flux powder mesh for optimun filling capability size. It is expected that filler structures will be ready for filling procedure evaluation in June.

Sincerely yours,

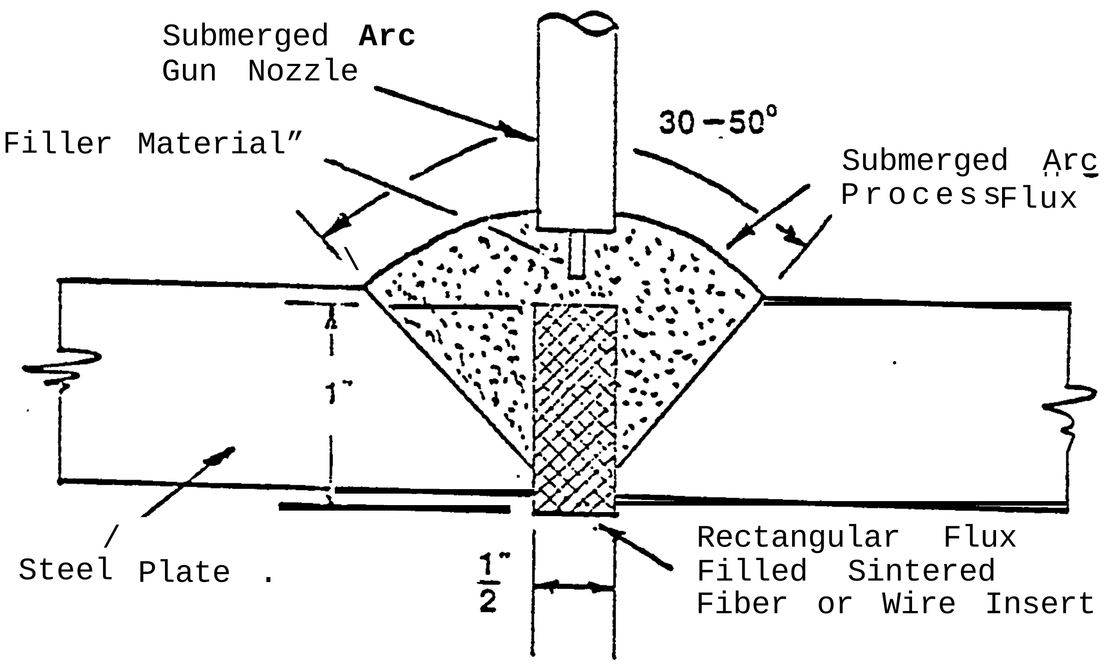
E.R. Bangs

E. R. Bangs, Manager
Welding & Joining R&D

Maurice AH Howes.

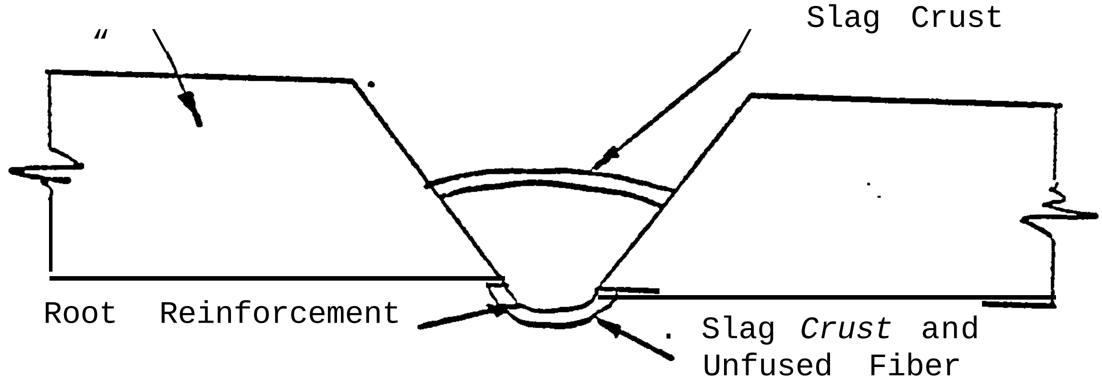
Maurice A. H. Howes
Director, Metals Research

ERB : bw



Weld Joint and **Insert** Position Prior to Arc Initiation

(a)



Fusion Zone Geometry Upon Completion of First **Pass**

(b)

Figure 1
The Flux Filled Consumable Insert
Before and After Welding

FLUX FILLED CONSUMABLE INSERT
FOR SUBMERGED ARC WELDING

MILESTONES

I. Design General Sintered Fiber Structure
   a) Material
   b) Wire size
   c) Density
   d) Sintering cycle

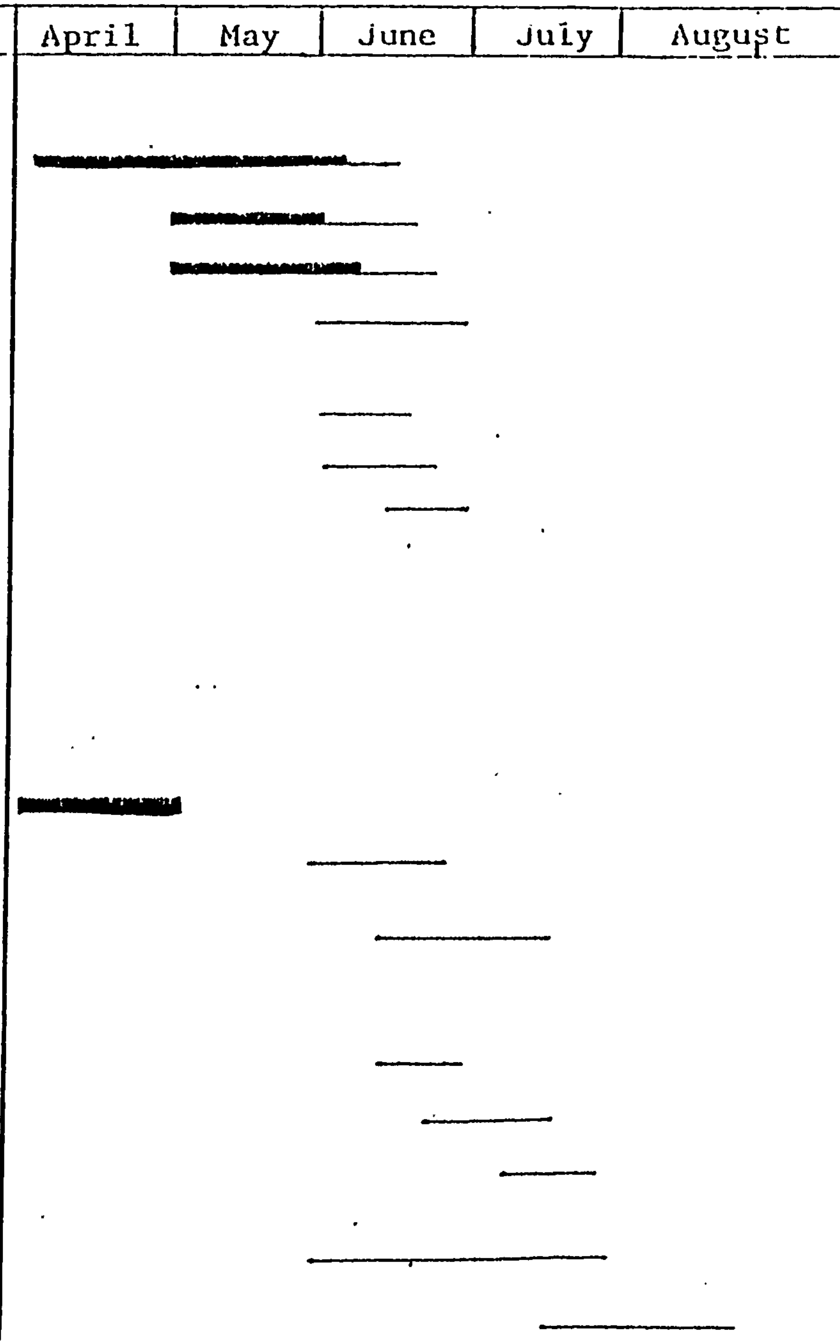
II. Flux Filling Procedure Development
   a) Define flux mesh size
   b) Dry and wet slurries
   c) Subsequent pressing

III. Final Insert Sizing
   a) Pressing
   b) Rolling
   c) Cutting

IV. Initial Laboratory Welding Trials
   a) Identify welding equipment
   b) Welding trials on presently available fiber structures
   c) Welding trials on filled structures from I, II, and III

V. Metallurgical Analysis of Welding Joints
   a) Geometric examination
   b) Macrostructural analysis
   c) Defect content

VI. Shipyard Welding Trials
   a) Define structures to be welded
   b) Witness welding trials



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11 July 1977
IITRI-B6143-3

Bethelem Steel Corp.
Sparrows Points, Maryland 21219

Attention: Mr. W. C. Brayton
Assistant General Manager

MAIN FILES
JUL 13 1977,
C. P.

Subject: Report No. IITRI-B6143-3 , "Development of a Composite Consumable Insert for Submerged Arc Welding," June 1977 Summary Report

Dear Bill:

Work continued during June with the sintering and filling of four sample insert structures 1/4 x 3/8 x 2 in. The structures were made of available wire (type 304 stainless steel> . The insert densities were 36, 41, 47;"and 57%. The porous network was filled with flux using liquid slurry techniques. The filled structures had a smooth, dense, void-free surface when drying was completed. It was determined by weight analysis that approximately 40% of the void volume still did not contain flux. However, the structures were excessively rigid, which will be a problem in their ability to adapt to joints with marginal fitup. Initial welding trials are scheduled to start on July 8th.

At present we are preparing two inserts 1/2 x 1 x 24 in. at two densities, 15 and 35%, in low carbon steel wire. The 15% dense structure will be flux filled using dry techniques which should, in addition to the lower structure density, improve flexibility.

In summation the flux-filling procedures have proceeded better than anticipated. After some welding trials we will know better the wire-to-flux weight ratio that will produce the most effective root area shielding.

Sincerely,

E. R. Bangs

E. R. Bangs, Manager
Welding & Joining R&D

Maurice AH Howes.

Maurice A. H. Howes
Director, Metals Research

FLUX FILLED CONSUMABLE INSERT
FOR SUBMERGED ARC WELDING

MILESTONES

I. Design General Sintered Fiber Structure
- a) Material
- b) Wire size
- c) Density
- d) Sintering cycle

II. Flux Filling Procedure Development
- a) Define flux mesh size
- b) Dry and wet slurries
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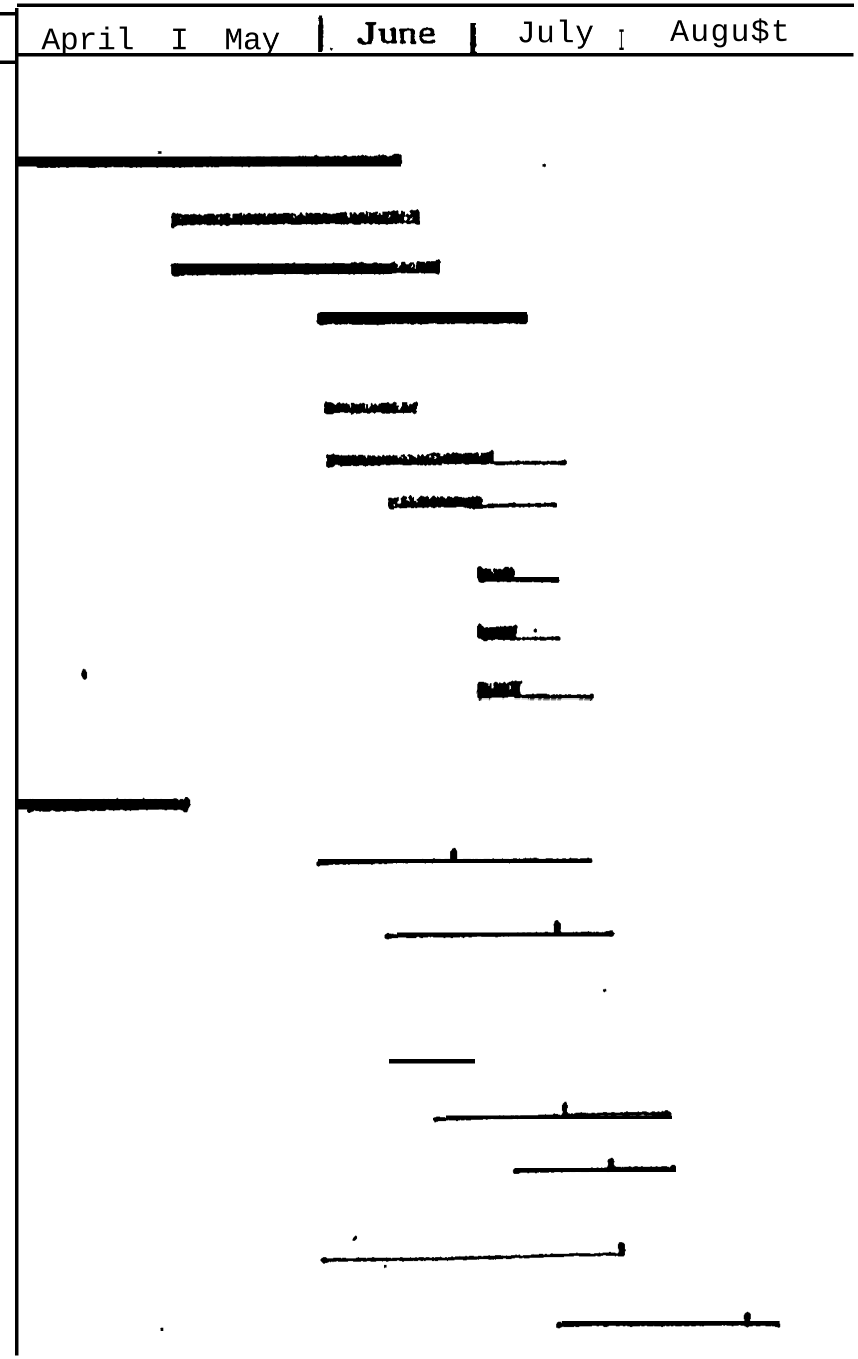

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10 West 35 Street, Chicago, Illinois 60616
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C.P.

15 August 1977
IITRI-B6143-4

Bethlehem Steel Corporation
Sparrows Point, Maryland 21219

Attention: Mr. W. C. Brayton
Assistant General Manager

Subject: Report No. IITRI-B6143-4, "Development of a Composite Consumable Insert for Submerged Arc Welding," July 1977 Summary Report

Dear Bill:

Work continued during July with welding trials and manufacture of low carbon steel sintered fiber structures to be evaluated as a consumable insert as well as a removable backing strip.

Welding trials have been completed on' stainless steel type 304 fiber structures sintered from 0.018 in. diameter wire which were used in the weld joint as a consumable insert. The insert was sandwiched between the 1 in. plate at the root area of the. joint as shown in Fig. 1 with a supporting grooved backup bar. Utilizing a manually operated submerged arc gun, the insert was consumed during the initial root pass welding. An 0.060 in. diameter filler wire was used in the welding of the root pass to compensate for the insufficient solid metal available in the fiber-filled insert, The welding parameters used and results obtained are listed in Table 1.

In general, initial test results produced an irregular weld deposit face and a root reinforcement containing a rough surface. A portion of the root reinforcement was removed by surface grinding flush to the bottom surface of the plate and was examined with red dye penetrant. the dye penetrant examination revealed a low defect fusion zone and adjacent heat-affected zone.

During the reporting period weld trials were also performed on the fiber flux filled pad positioned at the bottom of the weld joint in the form of a removable backing pad. As shown in Fig. 2,. the initial welded sample evaluated employed a backing pad made of steel fibers (.013 in. "x .017 in (oval), 50% density) 1/2 in. thick x 1 in wide. The weld was made using the parameters listed in Table 2, Upon completion of welding, the backing strip was intact and visually unaffected by heat. on its external surfaces. The pad was easily removed by mechanical scraping.1 Examination of the root area revealed a marginal amount bf penetration with continuous root area suck up. The root surface contained a high quality surface finish, and there was no evidence of cold lapping *or* lack of fusion. Additional examination of the welded sample continues at this time.

Sincerely yours,

E. R. Bangs

E. R. Bangs, Manager
Welding & Joining R&D

Maurice A H Howes.

Maurice A H. Howes
Director, "Metals Research

Table 1

WELDING PROCEDURE DEVELOPMENT FOR FLUX-FILLED FIBER CONSUMABLE INSERT

Insert Design[a] Cross. Dimen.	Insert Design[a] Density, %	Material	Amperage	Voltage	Filler Wire Diam., in.	Filler Wire Grade	Rate of Travel, ipm	Observations
.200 x .385	36	S.S. 304	500	32	0.075	L-61 (Lincoln)	7-8	Good surface and base metal fusion at groove side walls. Excessive root area penetration, cold laps at root reinforcement surface, surface grinding of root produced low defect level.
.400 x .385	41	S.S. 304	500	32	0.075	L-61 (Lincoln)	7-8	Lack of fusion at face in groove side walls. Excessive penetration and root reinforcement, rough root area surface, low defect level after grinding.
.310 x .400	57	S.S. 304	500	32	0.075	L-61 (Lincoln)	7-8	Good surface and base metal fusion at groove side wall. Excessive root area penetration, cold laps at root surface, low defect level after grinding.

[a]Fiber wire diameter = 0.008 in.

Table 2

WELDING PROCEDURE DEVELOPMENT FOR FLUX-FILLED FIBER REMOVABLE BACKING PAD

Baking Pad[a]								
Cross. Dimen.	Density, %	Material	Amperage	Voltage	Filler Wire Diam., in.	Filler Wire Grade	Rate of Travel, ipm	observations
3/8 x 1	50	Low carbon steel	500	32	0.075	L-61	6-7	Marginal penetration wit continuous root area suc Up. Weld face and root surface contained no defects (as-welded conditic

[a]Fiber wire diameter (oval) = 0.013-0.017 in.

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10 West 35 Street, Chicago, Illinois 60616
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September 16, 1977

Bethlehem Steel Corporation
Sparrows Point, Maryland 21219

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OCT 10 1977

Attention: Mr. W. C. Brayton
Assistant General Manager

C.P.

Subject: Report No. IITRI B6143-5, "Development of a Composite Consumable Insert for Submerged Arc welding", August 1977 Summary Report

Dear Bill:

Work continued during August with welding trials on low density fiber structures placed in the joint as consumable inserts and structures placed at the root area of the joint in the form of a removable backing strip.

Using the welding process parameters shown in Table 1, the insert consumption root pass was applied over the insert in a butt joint in plate l-inch thick. The lower portion of the insert extended past the lower surface of the plate approximately 0.200 inches in order to provide sufficient weld metal for a root area reinforcement. Excessive burn-through occurred adjacent to the insert in the land area of the plate. Upon close examination it appeared that there was insufficient mass available in the land region of the plate preparation to transfer sufficient heat from the molten puddle region and still physically suprort the puddle. Design changes will be incorporated in the plate preparation to increase the mass in the land region by increasing the land face dimension. The thickness dimension of the insert will be reduced from 0.500 inches to 0.250 inches.

A low carbon steel flux filled fiber structure at 52% density was applied to the back of the joint and welded in place, using a reduced heat input as shown in Table 2 and a root opening reduced from 0.250 to 0.187 inches. The results obtained in the test were the best achieved this far. The completed joint in the as welded condition contained the backing pad firmly attached to the root area of the joint with no evidence of burn-through or discoloration. The pad was removed for approximately 50% of the joint which revealed a uniform low defect root reinforcement. Additional non-destructive testing and microstructure examination is being completed.

Bathlehem Steel Corp .
Attn: Mr. W. C. Bravton

The flux filled fiber structures being used in the program consist principally of a series of oval mass section fibers approximately 2 inches in lenlm:gth that have been compacted and sintered in a reducing atmosphere furnace at 2200°F for two hours. The sintered porous structures are then infiltrated with a 320 mesh flux powder and water slurry. The flux slurry fills approximately 50-70% of the total void volume in the sintered structure.

Sincerely yours ,

E.R. Bangs

E. R. Bangs, Manager
Welding and Joining R & D

Maurice AH Howes

Maurice A. H, Howes
Director, Metals Research

Table 1

WELDING PROCEDURE DEVELOPMENT FOR FLUX-FILLED FIBER CONSUMABLE INSERT

Test No.	Insert Cross. Dimen. in.	Design[a] Density, %	Material	Amperage	Voltage	Filler Wire Diam., in.	Filler Wire Type	Rate of Travel, ipm	Heat Input Joules per in.	Observation
4	½ x 1	32	Low Carbon Steel	400	35	0.075	L-61	14-16	56,000	Excessive burnthrou in land region or o end preparation

[a]Fiber Wire Diameter (Oval) = 0.013 -O.017 in.

Table 2 .

WELDING PROCEDURE DEVELOPMENT FOR FLUX-FILLED FIBER REMOVABLE BACKING PAD

Test No.	Insert Cross. Dimen. in.	Design Density, %	Material	Amperage	voltage	Filler Wire Diam. in.	Filler Wire TYPE	Rate of Travel, ipm	Heat Input Joules per in.	Observations
3	½ x 1	52	Low Carbon Steel	400	35	0.075	L-61	12-14	64,600	Approx. 50% of root penetration into bac strip uniform low de level reinforcement

[a]Fiber Wire Diameter (Oval) = 0.013-0.017 in.

FLUX FILLED CONSUMABLE INSERT FOR SUBMERGED ARC WELDING

MILESTONES

I. Design General' Sintered Fiber Structure

- a) Material
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